PATENT

In the United States Patent and Trademark Office

Applicant: L. Rosenberg et al.
Applicant's Ref: IMM018B
Application No: Unassigned
Filed: August 20, 2001
Title: Interactions Between Simulated Objects with Force Feedback (as amended)

Examiner: Unknown
Group Art Unit: Unknown

PRELIMINARY AMENDMENT

Commissioner for Patents
Washington, D.C. 20231

Dear Sir:

Please amend the above-identified patent application as follows before the examination of the application:

In the Title:

Please delete the Title and replace with the following: -- Interactions Between Simulated Objects using with Force Feedback --.

In the Abstract:

A sheet having a new abstract is attached hereto.

CLEAN VERSION OF AMENDMENTS

In the Specification:

Replace the paragraph starting on Page 1, line 6, with:

The present application is a continuation of pending Application No. 09/433,657 filed 11/3/99 on behalf of Rosenberg et al., which is a continuation of Application No. 08/664,086, filed June 14, 1996, now Patent No. 6,028,593, which is a continuation-in-part of U.S. Patent Application Nos. 08/566,282, filed December 1, 1995, now Patent No. 5,734,373; and 08/571,606, filed December 13, 1995, now Patent No. 6,219,032; and where said Application No. 08/664,086 claims the benefit of provisional application No. 60/017,803, filed May 17, 1996, all of which are incorporated herein by reference for all purposes.

Replace the paragraph starting on Page 9, line 30, with:

User object 34 is preferably coupled to sensors 28 and actuators 30 by a mechanical apparatus which provides a number of degrees of freedom to the user object. Such a mechanical apparatus can take a variety of forms, from a simple rotary joint or linear coupling allowing a single degree of freedom, to a complex mechanical linkage allowing multiple degrees of freedom to the user object. Examples of mechanical apparatuses are described in Patent Nos. 5,576,727; 5,731,804; 5,767,839; 5,721,566; and 5,805,140, all of which are hereby incorporated by reference herein. Preferred embodiments of mechanical apparatuses suitable for sporting simulations disclosed herein are described subsequently with reference to Figures 14-18.

Replace the paragraph starting on Page 11, line 3, with:

In the described embodiment, host computer system 12 implements a host application program with which a user 22 is interacting via peripherals and interface device 14. For example, the host application program can be a video game, medical simulation, scientific analysis program, or even an operating system or other application program that can utilize force feedback. Typically, the host application provides images to be displayed on a display output device, as described below, and/or other feedback, such as auditory signals. For example, a graphical user interface for an operating system is described in greater detail in Patent No. 6,219,032, which is hereby incorporated by reference herein.

Replace the paragraph starting on Page 13, line 3, with:

An advantage of the present embodiment is that low-bandwidth serial communication signals can be used to interface with interface device 14, thus allowing a user to directly use a standard built-in serial interface of many low-cost computers. Alternatively, a parallel port of host computer system 12 can be coupled to a parallel bus 24 and communicate with interface device using a parallel protocol, such as SCSI or PC Parallel Printer Bus. In a different embodiment, bus 24 can be connected directly to a data bus of host computer system 12 using, for example, a plug-in card and slot or other access of computer system 12. For example, on an IBM AT compatible computer, the interface card can be implemented as an ISA, EISA, VESA local bus, PCI, or other well-known standard interface card. Other types of interfaces 14 can be used with other computer systems. In another embodiment, an additional bus 25 can be included to communicate between host computer system 12 and interface device 14. Since the speed requirement for communication signals is relatively high for outputting force feedback signals, a single serial interface used with bus 24 may not provide signals to and from the interface device at a high enough rate to achieve realistic force feedback. Bus 24 can thus be coupled to the standard serial port of host computer 12, while an additional bus 25 can be coupled to a second port of the host computer system, such as a "game port" or other port. The two buses 24 and 25 can be used simultaneously to provide an increased data bandwidth. Such an embodiment is described in greater detail in Patent No. 5,691,898, which is hereby incorporated by reference herein.

Replace the paragraph starting on Page 17, line 7, with:

Other types of interface circuitry 36 can also be used. For example, an electronic interface is described in U.S. Patent No. 5,576,727, assigned to the same assignee as the present application, and which is hereby incorporated by reference herein. The interface allows the position of the mouse or stylus to be tracked and provides force feedback to the stylus using sensors and actuators. Sensor interface 36 can include angle determining chips to pre-process angle signals reads from sensors 28 before sending them to the microprocessor 26. For example, a data bus plus chip-enable lines allow any of the angle determining chips to communicate with the microprocessor. A configuration without angle-determining chips is most applicable in an embodiment having absolute sensors, which have output signals directly indicating the angles without any further processing, thereby requiring less computation for the microprocessor 26 and thus little if any pre-processing. If the sensors 28 are relative sensors, which indicate only the

change in an angle and which require further processing for complete determination of the angle, then angle-determining chips are more appropriate.

Replace the paragraph starting on Page 18, line 28, with:

Power supply 40 can optionally be coupled to actuator interface 38 and/or actuators 30 to provide electrical power. Active actuators typically require a separate power source to be driven. Power supply 40 can be included within the housing of interface device 14, or can be provided as a separate component, for example, connected by an electrical power cord. Alternatively, if the USB or a similar communication protocol is used, interface device 14 can draw power from the bus 24 and thus have no need for power supply 40. Such an embodiment is described in greater detail in Patent No. 5,691,898.

Replace the paragraph starting on Page 19, line 4, with:

Safety switch 41 can be included in interface device 14 to provide a mechanism to allow a user to override and deactivate actuators 30, or require a user to activate actuators 30, for safety reasons. Certain types of actuators, especially active actuators such as motors, can pose a safety issue for the user if the actuators unexpectedly move user object 34 against the user with a strong force. In addition, if a failure in the control system 10 occurs, the user may desire to quickly deactivate the actuators to avoid any injury. To provide this option, safety switch 41 is coupled to actuators 30. In one embodiment, the user must continually activate or close safety switch 41 during operation of interface device 14 to activate the actuators 30. If, at any time, the safety switch is deactivated (opened), power from power supply 40 is cut to actuators 30 (or the actuators are otherwise deactivated) as long as the safety switch is deactivated. Examples of safety switches are described in Patent No. 5,691,898.

Replace the paragraph starting on Page 22, line 31, with:

For example, a kinematic equation which calculates a force based on the velocity of the user object multiplied by a damping constant can be used to determine a damping force on the user object. This type of equation can simulate motion of object 34 along one degree of freedom through a fluid or similar material. A procedure for calculating a damping force on object 34 is described in Patent No. 5,767,839, which is hereby incorporated by reference herein. For example, a damping constant can first be selected which indicates the degree of resistance that

object 34 experiences when moving through a simulated material, such as a liquid, where a greater number indicates greater resistance. For example, water would have a lower damping constant than oil or syrup. The host computer recalls the previous position of user object 34 (along a particular degree of freedom), examine the current position of the user object, and calculate the difference in position. From the sign (negative or positive) of the difference, the direction of the movement of object 34 can also be determined. The force is then set equal to the damping constant multiplied by the change in position. Commands that controlled an actuator based on this algorithm would produce a force proportional to the user object's motion to simulate movement through a fluid. Movement in other mediums, such as on a bumpy surface, on an inclined plane, etc., can be simulated in a similar fashion using different methods of calculating the force.

Replace the paragraph starting on Page 26, line 23, with:

In an alternate embodiment having host computer 12 directly control force feedback, a local microprocessor 26 (as shown in Figure 2) can be included in interface device 14 to assist in relaying sensor and actuator data to and from the host and for commanding forces to be output as long as there is no change in forces. This type of embodiment is not a "reflex" embodiment as described in Figure 4 since forces output by interface device 14 are dependent on active and continuous control from the host computer. Such an embodiment is described in greater detail in Patent Nos. 5,739,811 and 5,734,373, both incorporated by reference herein. For example, in step 80 above, the host computer can check if there is a change in force required on user object 34 depending on the above-described parameters. If not, then the host need not issue a low-level command, since local microprocessor could continue to issue the previous low-level command. The local microprocessor 26 can also convert a low-level command to an appropriate form before it is sent to actuators 30.

Replace the paragraph starting on Page 27, line 28, with:

The process of Figure 4 is suitable for low speed communication interfaces, such as a standard RS-232 serial interface. However, the embodiment of Figure 4 is also suitable for high speed communication interfaces such as USB, since the local microprocessor relieves computational burden from host processor 16. In addition, this embodiment can provide a straightforward command protocol, an example of which is described with respect to Patent No.

5,734,373, incorporated by reference herein, and which allows software developers to easily provide force feedback in a host application.

Replace the paragraph starting on Page 30, line 1, with:

If no change in the type of force is currently required in step 110, then the process returns to step 106 to update the host application and return to step 110 to again check until such a change the type of force is required. When such a change is required, step 112 is implemented, in which host computer 12 determines an appropriate host command to send to microprocessor 26. The available host commands for host computer 12 can correspond to an associated force routine implemented by microprocessor 26. For example, different host commands to provide a damping force, a spring force, a gravitational pull, a bumpy surface force, a virtual obstruction force, and other forces can be available to host computer 12. These host commands can also include a designation of the particular actuators 30 and/or degrees of freedom which are to apply this desired force on object 34. The host commands can also include other command parameter information which might vary the force produced by a particular force routine. For example, a damping constant can be included in a host command to designate a desired amount of damping force, or a direction of force can be provided. The host command may also preferably override the reflex operation of the processor 26 and include low-level force commands directly sent to actuators 30. A preferred command protocol and detailed description of a set of host commands is described in Patent No. 5,734,373. These commands can include direct host commands, "reflex" commands, and custom effects. Each direct host command preferably includes parameters which help the host specify the characteristics of the desired output force and may include a specified force routine. "Reflex" commands, in contrast, provide conditions to the microprocessor so that the desired force is output when the conditions are met, such as when a specified button is pressed by the user. Custom effects can be provided to the microprocessor 26 by the host and then commanded to be output. For example, the host computer can download to the microprocessor a set of force values (a force profile) as a "force profile file" or other collection of data using a host command LOAD_PROFILE; a separate host command PLAY_PROFILE could then be sent to instruct the microprocessor to output the downloaded force profile as forces on user object 34, or when a condition occurs, etc. For example, a force profile file can include an array of force values, size information about the size of the data, and timing information for when to output the various force values.

Replace the paragraph starting on Page 30, line 1, with:

Embodiments using a local microprocessor 26 to implement reflex processes is described by Patent Nos. 5,739,811 and 5,734,373, both assigned to the assignee of this present application, and both hereby incorporated by reference herein.

Replace the paragraph starting on Page 40, line 4, with:

Figures 6a-6h show how paddle object 220 interacts with a moving ball object 206 as ball object 206 collides with the paddle object. In Figure 6a, ball 206 first impacts paddle 220. Preferably, an initial force is applied to user object 34 in the appropriate (corresponding) direction of the ball's movement. In Figures 6b and 6c, ball 206 is moving into the compliant paddle or "sling." Preferably, a force based on a simulated mass of ball 206 (and/or other simulated conditions) is felt by the user through user object 34 which is appropriate to the simulated velocity of the ball (and/or the paddle), the simulated compliance of the paddle (and/or the ball), and the strength and direction of simulated gravity. In a local microprocessor embodiment, as described in Figure 4, these factors (and other desired physical factors) can preferably be set using a host command with the appropriate parameters, as described in Patent No. 6,219,032. For example, parameters of objects can be specified and simulated such as mass of the ball, velocity of the ball, the strength of gravity, the direction of gravity, the compliance or stiffness of the paddle object 220, damping forces to the collision between the ball and paddle, a simulated mass of the paddle 220, and other parameters to control other physical aspects of the computer environment and interaction of objects. In addition, the ball 206 can be displayed as a compressed object when it impacts paddle 220, with, for example, an oval or elliptical shape. Also, the parameters such as the compliance and/or damping of the paddle might be allowed to be adjusted by the user with other input 39 or an additional degree of freedom of a user object 34 manipulated by the user.

Replace the paragraph starting on Page 40, line 4, with:

An interface apparatus providing two linear (X and Y) degrees of freedom to user object 34 as well as a rotating ("spin") third degree of freedom about a Z axis is quite suitable for the paddle-ball implementation. Linear degree of freedom apparatuses are disclosed in Patent Nos. 5,721,566 and 5,805,140, previously incorporated herein, and further embodiments of such are described below.

In the Claims:

All pending claims are set forth below. Claims that have been changed by this amendment are marked as "amended."

Please cancel claims 1-76 without prejudice.

Please add the following claims:

77. (new) A computer readable medium including program instructions for simulating the spatial interaction of a displayed first simulated object with a displayed second simulated object in a computer-simulated spatial environment such that the user is provided with a force feedback that realistically represents said interaction, said program instructions performing the following on a computer system:

executing a simulation including a first simulated object, said simulation being configured to implement the motion of said first simulated object in response to motion of a physical object of an interface device controlled by a user, wherein said physical object has a physical position in a physical workspace, and wherein a position control mapping between said simulated location of said first simulated object and said physical position of said physical object exists, said simulation being further configured to generate a second simulated object having boundaries such that said second simulated object impedes the simulated motion of said first simulated object when the trajectory of said first simulated object intersects said boundaries of said second simulated object;

providing information causing a display device to display the location and motion of said first simulated object and said second simulated object such that when said first simulated object and second simulated object collide, the first simulated object is displayed at the boundary of the second simulated object as if unable to substantially penetrate said second simulated object, even if the motion of said physical object would indicate that a penetration should occur with respect to the position control mapping; and

providing information causing a force feedback mechanism to impart to a user of said force feedback mechanism a physical sensation that corresponds to the simulated physical

interaction of said first simulated object with said second simulated object when the trajectory of said first simulated object intersects the boundaries of said second simulated object.

78. (new) The computer readable medium of claim 77, wherein said physical sensation includes a restoring force that is proportional to an amount of said penetration of said second simulated object.

79. (new) The computer readable medium of claim 78, wherein said restoring force includes a spring force having the mathematical form:

$$F = kx$$

where F is said restoring force, x is a magnitude of a deviation of said spatial correlation including a deviation between the current location of the first simulated object and a location of said first simulated object had said mapping not been broken, and k is a spring constant parameter.

80. (new) The computer readable medium of claim 79, wherein said restoring force includes a damping force and said restoring force has the mathematical form:

$$F = kx + bv$$

where F is said restoring force, x is a magnitude of a deviation of said spatial correspondence including a deviation between the current location of the first simulated object and a location of said first simulated object had said mapping not been broken, v is a function of a velocity of said physical object, and k and b are constant parameters.

81. (new) The computer readable medium of claim 80, wherein said restoring force includes an intertial force corresponding to the movement of said second simulated object in response to said interaction between said second simulated object and said first simulated object and said restoring force has the mathematical form:

$$F = kx + bv + ma$$

where F is said restoring force, x is a magnitude of a deviation of said spatial correspondence including a deviation between the current location of the first simulated object and a location of said first simulated object had said mapping not been broken, v is a function of

a velocity of said physical object, a is a function of an acceleration of said physical object, and k, b and m are constant parameters.

82. (new) The computer readable medium of claim 78, wherein said restoring force includes a component resulting from friction between said simulated object and said simulated spatial environment.

83. (new) The computer readable medium of claim 78, wherein said second simulated object moves on said display device during said simulation in response to manipulations of a second physical object of a second interface device by said second user, said second interface device being coupled to a second computer system coupled to said computer system through a network interface.

84. (new) The computer readable medium of claim 78, wherein said restoring force includes a weighting factor such that the location L on said display device of the simulated objects shown on said display device is determined by the equation:

$$L = \frac{(w_1 x_1 + w_2 x_2)}{(w_1 + w_2)}.$$

85. (new) The computer readable medium of claim 77, wherein said processor is coupled with a second processor executing said simulation, said second processor being responsive to input from a second interface device, said processors being coupled such that said simulations communicate input information from said interface devices.

86. (new) A method for providing an interaction between displayed objects in a graphical environment implemented by a host computer, wherein a user interfaces with said graphical environment using a force feedback device coupled to said host computer, the method comprising:

moving a first graphical object in response to movement of a user manipulatable object of said force feedback device by said user, said movement of said first graphical object provided according to said movement of said user manipulatable object;

determining whether said first graphical object has engaged a second graphical object by examining a path of said first graphical object in said graphical environment, said path determined by examining a current location of said first graphical object and a previous location of said first graphical object;

providing an illusion of rigidity of said second graphical object by displaying said first graphical object as remaining engaged with said second graphical object when said path of said first graphical object has been determined to move through said second graphical object according to said movement of said user manipulatable object; and

providing information that causes said force feedback device coupled to said host computer to output an opposing force on said user manipulatable object by at least one actuator in said force feedback device in a direction approximately opposite to said path of said first graphical object while said first graphical object is engaged with said second graphical object.

87. (new) A method as recited in claim 86 wherein said opposing force is a restoring spring force.

88. (new) A method as recited in claim 86 wherein said second graphical object is fixed in location within said graphical environment.

89. (new) A method as recited in claim 86 wherein said user is a first user, and wherein said second graphical object is moveable according to input from a second user of a second force feedback device coupled to said host computer.

90. (new) A method as recited in claim 89 wherein said host computer is a first host computer, and wherein said second force feedback device is coupled to a second host computer which is coupled to said first host computer via a network.

91. (new) A method as recited in claim 90 wherein said network is the World Wide Web.

92. (new) A method as recited in claim 86 wherein a friction force is output on said user manipulatable object when said user manipulatable object is moved in a direction corresponding to a direction approximately perpendicular to said path of engagement of said first graphical object while said first and second graphical objects are engaged.

93. (new) A method as recited in claim 92 wherein said friction force has a magnitude that is a function of said magnitude of said opposing spring force.

94. (new) A method for providing an interaction between displayed objects in a graphical environment implemented by a host computer, wherein a user interfaces with said graphical environment using a force feedback device coupled to said host computer, the method comprising:

(a) moving a first graphical object in response to movement of a user manipulatable object of said force feedback device by said user, said movement of said first graphical object provided according to said movement of said user manipulatable object;

(b) determining whether said first graphical object has engaged a second graphical object by examining a path of said first graphical object in said graphical environment, said path determined at least in part by examining a previous location of said first graphical object; and

(c) providing information that causes said force feedback device coupled to said host computer to output:

(i) an opposing force on said user manipulatable object by at least one actuator in said force feedback device when said user manipulatable object is moved in a direction approximately opposite to said path of said first graphical object while said first graphical object is engaged with said second graphical object; and

(ii) a friction force on said user manipulatable object by at least one actuator in said force feedback device when said user manipulatable object is moved in a direction corresponding to a direction approximately perpendicular to said path of engagement of said first graphical object while said first and second graphical objects are engaged.

95. (new) A method as recited in claim 94 wherein said opposing force is a spring force, and wherein said friction force has a magnitude that is a function of said magnitude of said opposing spring force.

96. (new) A method as recited in claim 94 further comprising breaking said position control mapping and providing an illusion of rigidity of said second graphical object by displaying said first graphical object as remaining engaged with said second graphical object when said path of said first graphical object has been determined to move through said second graphical object if said position control mapping were maintained.

97. (new) A method for providing an interaction between displayed objects in a graphical environment implemented by a host computer, wherein a user interfaces with said graphical environment using a tactile feedback device coupled to said host computer, the method comprising:

moving a first graphical object in response to movement of a user manipulatable object of said force feedback device by said user, said movement of said first graphical object provided according to said movement of said user manipulatable object;

determining whether said first graphical object has collided with a second graphical object by examining a path of said first graphical object in said graphical environment;

providing an illusion of rigidity of said second graphical object by displaying said first graphical object as remaining engaged with the surface of said second graphical object when said path of said first graphical object has been determined to move through the surface of said second graphical object according to said movement of said user manipulatable object; and

providing information that causes said tactile feedback device coupled to said host computer to output a sensation felt by said user, produced by at least one actuator in said tactile feedback device, corresponding with the displayed interaction between said first graphical object and said second graphical object.

REMARKS

Claims 77-97 are pending in this application. Claims 1-76 have been cancelled and claims 77-97 have been added by this preliminary amendment. Applicant reserves the right to reintroduce claims of comparable scope to the original claims in a continuation or other related application. Various updates to the specification have also been made.

Should the Examiner believe that a telephone conference would expedite the prosecution of this application, the undersigned can be reached at the telephone number set out below.

Respectfully submitted,

James R. Riegel
Reg. 36,651

San Jose, CA
408-467-1900

ABSTRACT

A method and apparatus for providing force feedback to a user operating a human/computer interface device and interacting with a computer-generated simulation. In one aspect, a computer-implemented method simulates the interaction of simulated objects displayed to a user who controls one of the simulated objects manipulating a physical object of an interface device. The position of the simulated object, as provided within the simulation and as displayed, is mapped to the physical position of the user object. This mapping can broken under conditions that are effective to provide force feedback to the user which imparts a physical sensation corresponding to the interaction of the simulated objects.

MARKED-UP VERSION OF AMENDMENTS

Replace the paragraph starting on Page 1, line 6, with:

The present application is a continuation of pending Application No. 09/433,657 filed 11/3/99 on behalf of Rosenberg et al., which is a continuation of Application No. 08/664,086, filed June 14, 1996, now Patent No. 6,028,593, which is a continuation-in-part of U.S. Patent Application [Applications Serial] Nos. 08/566,282, [entitled METHOD AND APPARATUS FOR CONTROLLING FORCE FEEDBACK INTERFACE SYSTEMS USING A COMPUTER INTERFACE,] filed December 1, 1995, now Patent No. 5,734,373; and 08/571,606, [entitled METHOD AND APPARATUS FOR PROVIDING FORCE FEEDBACK FOR A GRAPHICAL USER INTERFACE,] filed December 13, 1995, now Patent No. 6,219,032; and where said Application No. 08/664,086 claims the benefit of provisional application No. 60/017,803, [entitled METHOD AND APPARATUS FOR PROVIDING SIMULATED BARRIER CONTACT FOR GRAPHICAL USER INTERFACES,] filed May 17, 1996, all of which are incorporated herein by reference for all purposes.

Replace the paragraph starting on Page 9, line 30, with:

User object 34 is preferably coupled to sensors 28 and actuators 30 by a mechanical apparatus which provides a number of degrees of freedom to the user object. Such a mechanical apparatus can take a variety of forms, from a simple rotary joint or linear coupling allowing a single degree of freedom, to a complex mechanical linkage allowing multiple degrees of freedom to the user object. Examples of mechanical apparatuses are described in [co-pending patent applications serial numbers 08/461,170, 08/374,288, 08/400,233, 08/489,068, and 08/560,091,] Patent Nos. 5,576,727; 5,731,804; 5,767,839; 5,721,566; and 5,805,140, all of which are hereby incorporated by reference herein. Preferred embodiments of mechanical apparatuses suitable for sporting simulations disclosed herein are described subsequently with reference to Figures 14-18.

Replace the paragraph starting on Page 11, line 3, with:

In the described embodiment, host computer system 12 implements a host application program with which a user 22 is interacting via peripherals and interface device 14. For

example, the host application program can be a video game, medical simulation, scientific analysis program, or even an operating system or other application program that can utilize force feedback. Typically, the host application provides images to be displayed on a display output device, as described below, and/or other feedback, such as auditory signals. For example, a graphical user interface for an operating system is described in greater detail in [co-pending patent application serial no. 08/571,606, filed 12/13/95, by Rosenberg et al., and] <u>Patent No. 6,219,032,</u> which is hereby incorporated by reference herein.

Replace the paragraph starting on Page 13, line 3, with:

An advantage of the present embodiment is that low-bandwidth serial communication signals can be used to interface with interface device 14, thus allowing a user to directly use a standard built-in serial interface of many low-cost computers. Alternatively, a parallel port of host computer system 12 can be coupled to a parallel bus 24 and communicate with interface device using a parallel protocol, such as SCSI or PC Parallel Printer Bus. In a different embodiment, bus 24 can be connected directly to a data bus of host computer system 12 using, for example, a plug-in card and slot or other access of computer system 12. For example, on an IBM AT compatible computer, the interface card can be implemented as an ISA, EISA, VESA local bus, PCI, or other well-known standard interface card. Other types of interfaces 14 can be used with other computer systems. In another embodiment, an additional bus 25 can be included to communicate between host computer system 12 and interface device 14. Since the speed requirement for communication signals is relatively high for outputting force feedback signals, a single serial interface used with bus 24 may not provide signals to and from the interface device at a high enough rate to achieve realistic force feedback. Bus 24 can thus be coupled to the standard serial port of host computer 12, while an additional bus 25 can be coupled to a second port of the host computer system, such as a "game port" or other port. The two buses 24 and 25 can be used simultaneously to provide an increased data bandwidth. Such an embodiment is described in greater detail in [co-pending patent application serial no. 08/623,660, filed 3/28/96, by Rosenberg et al., and] <u>Patent No. 5,691,898,</u> which is hereby incorporated by reference herein.

Replace the paragraph starting on Page 17, line 7, with:

Other types of interface circuitry 36 can also be used. For example, an electronic interface is described in U.S. Patent [Application Serial No. 08/461,170, originally filed July 16,

1993, on behalf of Louis B. Rosenberg et al., entitled, "Three-Dimensional Mechanical Mouse,"] No. 5,576,727, assigned to the same assignee as the present application, and which is hereby incorporated by reference herein. The interface allows the position of the mouse or stylus to be tracked and provides force feedback to the stylus using sensors and actuators. Sensor interface 36 can include angle determining chips to pre-process angle signals reads from sensors 28 before sending them to the microprocessor 26. For example, a data bus plus chip-enable lines allow any of the angle determining chips to communicate with the microprocessor. A configuration without angle-determining chips is most applicable in an embodiment having absolute sensors, which have output signals directly indicating the angles without any further processing, thereby requiring less computation for the microprocessor 26 and thus little if any pre-processing. If the sensors 28 are relative sensors, which indicate only the change in an angle and which require further processing for complete determination of the angle, then angle-determining chips are more appropriate.

Replace the paragraph starting on Page 18, line 28, with:

Power supply 40 can optionally be coupled to actuator interface 38 and/or actuators 30 to provide electrical power. Active actuators typically require a separate power source to be driven. Power supply 40 can be included within the housing of interface device 14, or can be provided as a separate component, for example, connected by an electrical power cord. Alternatively, if the USB or a similar communication protocol is used, interface device 14 can draw power from the bus 24 and thus have no need for power supply 40. Such an embodiment is described in greater detail in [co-pending application 08/623,660] Patent No. 5,691,898.

Replace the paragraph starting on Page 19, line 4, with:

Safety switch 41 can be included in interface device 14 to provide a mechanism to allow a user to override and deactivate actuators 30, or require a user to activate actuators 30, for safety reasons. Certain types of actuators, especially active actuators such as motors, can pose a safety issue for the user if the actuators unexpectedly move user object 34 against the user with a strong force. In addition, if a failure in the control system 10 occurs, the user may desire to quickly deactivate the actuators to avoid any injury. To provide this option, safety switch 41 is coupled to actuators 30. In one embodiment, the user must continually activate or close safety switch 41 during operation of interface device 14 to activate the actuators 30. If, at any time, the safety switch is deactivated (opened), power from power supply 40 is cut to actuators 30 (or the

actuators are otherwise deactivated) as long as the safety switch is deactivated. Examples of safety switches are described in [co-pending patent application 08/623,660] Patent No. 5,691,898.

Replace the paragraph starting on Page 22, line 31, with:

For example, a kinematic equation which calculates a force based on the velocity of the user object multiplied by a damping constant can be used to determine a damping force on the user object. This type of equation can simulate motion of object 34 along one degree of freedom through a fluid or similar material. A procedure for calculating a damping force on object 34 is described in [co-pending patent application 08/400,233, filed 3/3/95, entitled "Method and Apparatus for Providing Passive Force Feedback",] Patent No. 5,767,839, which is hereby incorporated by reference herein. For example, a damping constant can first be selected which indicates the degree of resistance that object 34 experiences when moving through a simulated material, such as a liquid, where a greater number indicates greater resistance. For example, water would have a lower damping constant than oil or syrup. The host computer recalls the previous position of user object 34 (along a particular degree of freedom), examine the current position of the user object, and calculate the difference in position. From the sign (negative or positive) of the difference, the direction of the movement of object 34 can also be determined. The force is then set equal to the damping constant multiplied by the change in position. Commands that controlled an actuator based on this algorithm would produce a force proportional to the user object's motion to simulate movement through a fluid. Movement in other mediums, such as on a bumpy surface, on an inclined plane, etc., can be simulated in a similar fashion using different methods of calculating the force.

Replace the paragraph starting on Page 26, line 23, with:

In an alternate embodiment having host computer 12 directly control force feedback, a local microprocessor 26 (as shown in Figure 2) can be included in interface device 14 to assist in relaying sensor and actuator data to and from the host and for commanding forces to be output as long as there is no change in forces. This type of embodiment is not a "reflex" embodiment as described in Figure 4 since forces output by interface device 14 are dependent on active and continuous control from the host computer. Such an embodiment is described in greater detail in [co-pending patent applications serial no. 08/534,791 and serial no. 08/566,282,] Patent Nos. 5,739,811 and 5,734,373, both incorporated by reference herein. For example, in step 80 above,

the host computer can check if there is a change in force required on user object 34 depending on the above-described parameters. If not, then the host need not issue a low-level command, since local microprocessor could continue to issue the previous low-level command. The local microprocessor 26 can also convert a low-level command to an appropriate form before it is sent to actuators 30.

Replace the paragraph starting on Page 27, line 28, with:

The process of Figure 4 is suitable for low speed communication interfaces, such as a standard RS-232 serial interface. However, the embodiment of Figure 4 is also suitable for high speed communication interfaces such as USB, since the local microprocessor relieves computational burden from host processor 16. In addition, this embodiment can provide a straightforward command protocol, an example of which is described with respect to [patent application serial no. 08/556,282,] Patent No. 5,734,373, incorporated by reference herein, and which allows software developers to easily provide force feedback in a host application.

Replace the paragraph starting on Page 30, line 1, with:

If no change in the type of force is currently required in step 110, then the process returns to step 106 to update the host application and return to step 110 to again check until such a change the type of force is required. When such a change is required, step 112 is implemented, in which host computer 12 determines an appropriate host command to send to microprocessor 26. The available host commands for host computer 12 can correspond to an associated force routine implemented by microprocessor 26. For example, different host commands to provide a damping force, a spring force, a gravitational pull, a bumpy surface force, a virtual obstruction force, and other forces can be available to host computer 12. These host commands can also include a designation of the particular actuators 30 and/or degrees of freedom which are to apply this desired force on object 34. The host commands can also include other command parameter information which might vary the force produced by a particular force routine. For example, a damping constant can be included in a host command to designate a desired amount of damping force, or a direction of force can be provided. The host command may also preferably override the reflex operation of the processor 26 and include low-level force commands directly sent to actuators 30. A preferred command protocol and detailed description of a set of host commands is described in [co-pending patent application serial no. 08/566,282] Patent No. 5,734,373. These commands can include direct host commands, "reflex" commands, and custom effects.

Each direct host command preferably includes parameters which help the host specify the characteristics of the desired output force and may include a specified force routine. "Reflex" commands, in contrast, provide conditions to the microprocessor so that the desired force is output when the conditions are met, such as when a specified button is pressed by the user. Custom effects can be provided to the microprocessor 26 by the host and then commanded to be output. For example, the host computer can download to the microprocessor a set of force values (a force profile) as a "force profile file" or other collection of data using a host command LOAD_PROFILE; a separate host command PLAY_PROFILE could then be sent to instruct the microprocessor to output the downloaded force profile as forces on user object 34, or when a condition occurs, etc. For example, a force profile file can include an array of force values, size information about the size of the data, and timing information for when to output the various force values.

Replace the paragraph starting on Page 30, line 1, with:

Embodiments using a local microprocessor 26 to implement reflex processes is described by [copending parent applications 08/534,791, filed September 27, 1995 on behalf of Rosenberg, entitled "Method and Apparatus for Controlling Human-computer Interface Systems Providing Force Feedback, and U.S. patent application Serial no. 08/566,282, entitled "Method and Apparatus for Controlling Force Feedback Interface Systems Utilizing a Host Computer," filed 12/1/95 on behalf of Louis B. Rosenberg et al.,] <u>Patent Nos. 5,739,811 and 5,734,373,</u> both assigned to the assignee of this present application, and both hereby incorporated by reference herein.

Replace the paragraph starting on Page 40, line 4, with:

Figures 6a-6h show how paddle object 220 interacts with a moving ball object 206 as ball object 206 collides with the paddle object. In Figure 6a, ball 206 first impacts paddle 220. Preferably, an initial force is applied to user object 34 in the appropriate (corresponding) direction of the ball's movement. In Figures 6b and 6c, ball 206 is moving into the compliant paddle or "sling." Preferably, a force based on a simulated mass of ball 206 (and/or other simulated conditions) is felt by the user through user object 34 which is appropriate to the simulated velocity of the ball (and/or the paddle), the simulated compliance of the paddle (and/or the ball), and the strength and direction of simulated gravity. In a local microprocessor

embodiment, as described in Figure 4, these factors (and other desired physical factors) can preferably be set using a host command with the appropriate parameters, as described in [co-pending patent application serial no. 08/571,606] Patent No. 6,219,032. For example, parameters of objects can be specified and simulated such as mass of the ball, velocity of the ball, the strength of gravity, the direction of gravity, the compliance or stiffness of the paddle object 220, damping forces to the collision between the ball and paddle, a simulated mass of the paddle 220, and other parameters to control other physical aspects of the computer environment and interaction of objects. In addition, the ball 206 can be displayed as a compressed object when it impacts paddle 220, with, for example, an oval or elliptical shape. Also, the parameters such as the compliance and/or damping of the paddle might be allowed to be adjusted by the user with other input 39 or an additional degree of freedom of a user object 34 manipulated by the user.

Replace the paragraph starting on Page 40, line 4, with:

An interface apparatus providing two linear (X and Y) degrees of freedom to user object 34 as well as a rotating ("spin") third degree of freedom about a Z axis is quite suitable for the paddle-ball implementation. Linear degree of freedom apparatuses are disclosed in [co-pending applications serial no. 08/489,068, and serial no. 08/560,091] Patent Nos. 5,721,566 and 5,805,140, previously incorporated herein, and further embodiments of such are described below.